ARIZONA DEPARTMENT
OF
ENVIRONMENTAL QUALITY

Douglas A. Ducey
Governor

Misael Cabrera
Director

via e-mail

October 25, 2016
FPU17-089

Ms. Catherine Jerrard
AFCEC/CIBW
706 Hangar Road
Rome, NY 13441

RE: WAFB – ADEQ Evaluation of USAF Response to ADEQ Comments – ST012 - *Submission of "Response to ADEQ Comments dated 20 April 2016; Response to EPA Comments dated 18 May 2016; Response to EPA Memorandum (Dr. Eva Davis) dated 8 June 2016; Response to EPA Comments Dated 17 June 2016 on the Remedial Design and Remedial Action Work Plan for Operable Unit 2 Draft Final Addendum #2, Former Liquid Fuels Storage Area, Site ST012, Former Williams Air Force Base, Mesa, Arizona"*; prepared for US EPA Region IX, San Francisco, CA and Arizona Department of Environmental Quality, Phoenix, AZ; prepared by Department of the Air Force, AFCEC/CIBW, Rome, NY; document dated August 22, 2016.

Dear Ms. Jerrard:

Arizona Department of Environmental Quality (ADEQ) Federal Projects Unit (FPU) and ADEQ contractors evaluated the above referenced correspondence. Thank you for your responses. However, ADEQ is requesting USAF provide clarification and additional elaboration for some USAF responses. For your use, ADEQ is submitting this evaluation and additional information request.

This evaluation format generally presents:
(a). The initial regulatory comment (numerically identified **Evaluation 1 ADEQ General Comment 5.)**;
(b). The subsequent U.S. Air Force AFCEC/CIBC (USAF) response (***Air Force Response to ADEQ General comment 5:)***; and,
(c). ADEQ's evaluation **ADEQ Evaluation of Air Force Response to ADEQ General comment 5:**).

The initial ADEQ comment inclusion and the USAF response to comment purpose is to provide context to ADEQ's evaluation and information request.

Evaluation of Responses to Comments:

Evaluation 1 ADEQ General Comment 5. Please clarify how chloride concentrations are not expected to inhibit or slow EBR at this site. Chloride levels appear to be extremely high, and may inhibit some sulfate-reducing bacteria as well as others that are hoped to be used for target compound biodegradation during the EBR phase.

Air Force Response to ADEQ General comment 5:
It is recognized that chloride can, in general, inhibit cell growth. However, there are no literature or project examples that provide evidence to suggest high concentrations of chloride result in a reduction in effectiveness of sulfate-reducing bacteria. In fact, sulfate-reducing bacteria are common in high salinity marine environments. Based on review of groundwater sample results collected prior to remedial action at ST012, the existing consortia of microorganisms have readily utilized naturally-available TEAs such that the flux of TEAs are rate-limiting in the respiration of the petroleum. The presence of high background chloride levels did not appear to inhibit biodegradation; instead, biodegradation is likely limited by the availability of TEAs.
This discussion will be added to Section 3.1.2.

ADEQ Evaluation of Air Force Response to ADEQ General comment 5:

a. ADEQ reiterates its concern that the current population of sulfate-reducing bacteria is unknown and should be determined prior to the start of EBR.

Although there are many populations of sulfate-reducing bacteria that are known to survive and thrive in marine and even hyper-saline environments, these halotolerant communities have special adaptations to allow for this. The Williams AFB location is NOT naturally marine or hyper-saline in nature, and thus the indigenous microbial populations present may not have these special adaptations that would allow for survival in high concentrations of chloride. As a general rule, bacteria not adapted for high-chloride environments will die in the presence of high concentrations of the ion. The converse is also generally true: those bacteria adapted to survive in high saline conditions generally cannot survive if introduced to an environment with lower salt concentrations.

The response to this comment states that "there are no literature or project examples that provide evidence to suggest high concentrations of chloride result in a reduction in effectiveness of sulfate-reducing bacteria". Dissenting opinions to the response can be found in the following:

- Oren, A. Bioenergetic Aspects of Halophilism. Microbiol Mol Biol Rev. 1999. 63:334-348.
- Ben-Dov, E., et al. Changes in Microbial Diversity in Industrial Wastewater Evaporation Ponds Following Artificial Salination. 2008. FEMS Microbiology Ecology. 66: 437-446.
- Lonescu. D., et al. Microbial and Chemical Characterization of Underwater Fresh Water Springs in the Dead Sea. PLOS. 2012. 7:e38319

b. The response states, in part, that "Based on a review of groundwater sample results collected prior to remedial action at ST012, the existing consortia of microorganisms have readily utilized naturally-available TESs such that the flux of TEAs are rate-limiting in the respiration of the petroleum".

Please provide a reference to the specific data and explain how data obtained prior to SEE can show that TEAs are currently limited. Data collected prior to SEE is only applicable to the microbial population as it existed prior to the remedial actions. The status and makeup of the current population is likely very different from that observed prior to remedial actions.

Evaluation 2 **ADEQ General Comment 6.** Please clarify why sulfate should be added to a system that currently has sulfate levels in tested wells as high as 310 mg/L.

Air Force Response to ADEQ General Comment 6:
Sulfate as high as 310 mg/L are only present upgradient or in areas that do not contain significant COC concentrations. The flux of sulfate by natural groundwater movement through contaminated areas is not sufficient to degrade the remaining mass in the projected timeframe.
This discussion will be added to Section 3.1.2

ADEQ Evaluation of Air Force Response to ADEQ General Comment 6:
The Air Force RTC states that high sulfate concentrations are only found "upgradient or in areas that do not contain significant COC concentrations." However, a comparison of groundwater data provided in the August 24, 2016 preliminary analytical results table to visual slides presented at the August 24 BCT meeting, shows many of the wells with elevated sulfate concentrations appear to be within the LNAPL extent. Thus, it appears that high sulfate levels are found in areas of significant COC concentrations. Please address and reconcile this issue.

Evaluation 3. **ADEQ Specific Comment 2.** Please clarify the statement that, "sulfate amendment can either be used solely or in combination with aerobic methods to achieve remediation goals." The use of sulfate to stimulate the strongly anaerobic process of sulfate-reduction is not compatible with aerobic methods of bioremediation. Sulfate reduction occurs only under highly reduced environmental conditions, while aerobic respiration occurs only under highly oxidized environmental conditions. Thus, sulfate-reduction cannot be used in combination with aerobic methods.

Air Force Response to ADEQ Specific Comment 2:
The different TEAs could be implemented sequentially or in different areas. The sentence was revised as follows: "Sulfate amendment can either be used solely or in combination with aerobic methods (either sequentially or in different areas) to achieve remediation goals."

ADEQ Evaluation of Air Force Response to ADEQ Specific Comment 2:
Please explain how an aerobic method will be successfully used "sequentially" with a strongly anaerobic method such as sulfate-reduction. Please provide a peer-reviewed reference for such a "sequential" use of widely differing bioremediation methods for in-situ remediation of hydrocarbons.

Evaluation 4. **ADEQ Specific Comment 4.** See the evaluation of the response to ADEQ General Comment 1 (original comment date February 11, 2016). The statement assumes a priori knowledge that does not appear to exist regarding the indigenous microbial population. Furthermore, this statement assumes that sulfate-reducers dominate the indigenous population - something that has not been proven. ADEQ has specifically questioned and asked to have this investigated.

Air Force Response to ADEQ Specific Comment 4:
The point of the bullet is that the sulfate reducing bacteria stimulated by the EBR will also have a long-term source of sulfate from upgradient groundwater. With implementation of EBR, sulfate reducing bacteria will be the dominant established population. The dominant established population will be confirmed via microbial analysis between six and twelve months following the initiation of sulfate injections, as shown in Table 5-1. The bullet has been revised as follows to clarify: "influent upgradient background sulfate can supplement

sulfate amendments to promote petroleum hydrocarbon degradation during and after EBR without having to change the established bacterial populations or redox conditions;"

ADEQ Evaluation of Air Force Response to ADEQ Specific Comment 4:

a. The condition of sulfate-reducers dominating the current, indigenous microbial population has not been proven, and ADEQ requests that this be investigated.
b. Please explain how the AF plans to confirm changes from the "established" microbial and chemical conditions if current, "established" microbial populations and chemical conditions are not known prior to EBR inception. ADEQ suggests performing baseline microbial analyses in addition to geochemical sampling to establish the current site conditions. This would allow for proper and meaningful comparisons between the current conditions and those during and after EBR.

Evaluation 5. ADEQ Specific Comment 5. What specific "rate-limiting geochemical conditions" will be monitored, and what is the plan for maintaining effective EBR if one of these adverse conditions is encountered?

Air Force Response to ADEQ Specific Comment 5:
Changed text in Section 3.2.3:
"... or rate-limiting geochemical conditions (e.g., pH, oxidation-reduction potential (ORP), nitrogen and micronutrient concentration)."
If EBR is shown to be affected by monitored rate-limiting geochemical conditions, additional amendments may be added to the subsurface using the on-site injection system. A discussion of this situation is included in Section 4.2.3: Micronutrient Dosing.

ADEQ Evaluation of Air Force Response to ADEQ Specific Comment 5:
Please provide all data collected during sampling (i.e., all field parameters, water level measurements, sample depth, etc.) when transmitting preliminary analytical data.

Evaluation 6. ADEQ Specific Comment 7. Please detail how both population surge/crash and plugging of the formation with biomass will be prevented.

Air Force Response to ADEQ Specific Comment 7:
Biomass is expected to surge in the formation where sulfate concentrations are optimum and above twice half saturation. In these locations some level of formation plugging or reduction of pore space is inevitable, however; it is anticipated to have minimal negative consequences on the remediation of petroleum hydrocarbons. Conversely, the population surge will assist in retaining TEA in the vicinity of petroleum impacted media.

Microbial populations are expected to follow typical growth phases with the introduction of abundant TEA. The immediate response is generally a lag phase (little or no population growth) during which the microorganisms adjust or evolve to the change in geochemical conditions. As the consortium diversity realigns, exponential growth is anticipated until zero-order or maximum utilization is reached. Since the petroleum substrate is expected to change in bioavailability over time, variability in the maximum utilization rate and consortium diversity is also anticipated to change. Ultimately, the system is expected to return to natural or background levels and diversity as the petroleum hydrocarbon source and sulfate are degraded and mineralized.

The following text was added to Section 4.2.5:

"Biofouling. It is anticipated that the high ionic strength of the injection solution will reduce plugging of the formation with biomass by inhibiting microbial growth in the immediate vicinity of injection wells, thereby allowing use of these wells for future dosing. However, it is also anticipated that as sulfate concentrations drop at the injection well sites microbial blooms may occur along with biofouling of the well screen and filter pack. If the wells are affected by biofouling, one or more of the following two courses of action (or similar variations on these actions) will be implemented:

1. Injection wells will be pressurized to deliver TEA solutions into wells.

2. Injection and/or extraction wells will be redeveloped by mechanical removal (e.g., hydrojet, surge, bail) and/or chemical addition (e.g., biocide) could be employed to restore well function."

ADEQ Evaluation of Air Force Response to ADEQ Specific Comment 7:

a. Please clarify the phrase "twice half saturation." Does the AF propose injecting full saturation concentrations of sulfate, with expectations that this sulfate will actually travel through the formation? At full saturation concentrations, sulfate will precipitate out of solution.
b. Please explain how the anticipated plugging of formation pore spaces will "have minimal negative consequences on the remediation of petroleum hydrocarbons" when a wealth of published data specifically cites this issue as a strong and negative impact on overall mass reduction at sites. Multiple EPA guidance documents specifically cite plugging of a formation as a negative factor to avoid when trying to stimulate biodegradation. Please explain why it won't negatively impact hydrocarbon degradation at this location, when it is so strongly avoided in other locations.
c. Please explain how "the (resulting microbial) surge will assist in retaining TEC in the vicinity of the petroleum impacted media".
d. The AF response references "typical growth phases." Please explain how these microbial growth phases will be monitored during EBR. These growth curves are in response to total nutrient availability and not just a single element such as a terminal electron acceptor.
e. The response states that the addition of a biocide is a possible remedy to biofouling. However, the addition of a biocide may kill the very microbes needed for EBR to work. Please explain how poisoning of the hydrocarbon-degrading population will be avoided if biocide use is to occur. Include in this explanation the details of how the health of the hydrocarbon-degrading population will be confirmed during and after biocide use.

Evaluation 7. For reference please see *AF Response to ADEQ Evaluation (beginning on page 14):*

Item 3, ADEQ Evaluation.

3a) Please detail how the proper length of time for sampler deployment will be determined and followed. The response states that the Bio-trap® SIP sampler will be deployed for approximately one month before being retrieved for analysis. However, this is a general timeframe provided by Microbial Insights to be used as a starting point in determining the proper length of deployment time. This time length should be adjusted based on site geochemical conditions and target compounds. If the assumed sulfate-reducing conditions are dominant, then experience with these samplers in anaerobic environments suggests that one month may not be enough time to properly allow for adequate target compound mineralization or conversion to biomass.

Air Force Response to ADEQ Item 3 Evaluation:

3a) The timing for deployment of Bio-traps for stable isotope probing (SIP) following the addition of sulfate will be based on feedback from the groundwater sampling. Sulfate, COC concentrations, and general water

quality sample results will be used to assess the timing and final location for deployment of the post-sulfate addition SIP. It is important that the SIP be deployed after the lag-phase and preferably after the exponential growth-phase has occurred. Depending on the feedback from the groundwater analyses SIP may be deployed at more than one time step. Additionally, the duration of the deployment will be adjusted based on feedback; however, the one-month, rule-of-thumb will likely prevail as a reasonable timeframe for attachment and generation of at least some biofilm. The substrate utilization rates at zero-order are anticipated to be significantly higher than ambient biodegradation. At these higher rates reattachment and growth on the Bio-trap media is anticipated to be faster post-sulfate addition.

ADEQ Evaluation of Air Force Response to ADEQ Item 3 Evaluation:
The AF response references specific microbial growth stages. In particular, the AF response states that "it is important that the SIP be deployed after the lag-phase and preferably after the exponential growth-phase has occurred."

a. As only geochemical testing is referenced, will this time point be determined from a microbial standpoint?
b. If geochemical parameters are being correlated to, and will be used to determine in situ growth stages, please provide a peer-reviewed reference for this protocol for contaminated sites.

Closure

ADEQ may add or amend comments if evidence to the contrary of our understanding is discovered; if received information is determined to be inaccurate; if any condition was unknown to ADEQ at the time this document was signed; or if other parties bring valid and proven concerns to our attention; or site conditions are deemed not protective of human health and the environment within the scope of this Department.

Thank you for the opportunity to comment. Should you have any questions regarding this correspondence, please contact me by phone at (602) 771-4121 or e-mail miller.wayne@azdeq.gov.

Sincerely,

Wayne Miller
ADEQ Project Manager, Federal Projects Unit
Remedial Projects Section, Waste Programs Division

cc:	Catherine Jerrard, USAF AFCEC/CIBW	catherine.jerrard@us.af.mil
	Carolyn d'Almeida, U.S. EPA	dAlmeida.Carolyn@epamail.epa.gov
	Ardis Dickey, AFCEC/CIBW	ardis.dickey.ctr@us.af.mil
	Steve Willis, UXO Pro, Inc.	steve@uxopro.com
	ADEQ Reading and Project File	